International Journal of Psychophysiology 109 (2016) 138–146

Contents lists available at ScienceDirect

International Journal of Psychophysiology

journal homepage: www.elsevier.com/locate/ijpsycho

Long-term academic stress enhances early processing of facial expressions

Liang Zhang [a], Shaozheng Qin [b], Zhuxi Yao [a,c], Kan Zhang [a], Jianhui Wu [a,*]

[a] Key Laboratory of Behavioral Science, Institute of Psychology, Chinese Academy of Sciences, Beijing, China
[b] State Key Laboratory of Cognitive Neuroscience and Learning & IDG/McGovern Institute for Brain Research, Beijing Normal University, Beijing, China
[c] University of the Chinese Academy of Sciences, Beijing, China

ARTICLE INFO

Article history:
Received 2 September 2015
Received in revised form 11 August 2016
Accepted 23 August 2016
Available online 24 August 2016

Keywords:
Long-term stress
Event-related potentials
Facial expression
P1
P2

ABSTRACT

Exposure to long-term stress can lead to a variety of emotional and behavioral problems. Although widely investigated, the neural basis of how long-term stress impacts emotional processing in humans remains largely elusive. Using event-related brain potentials (ERPs), we investigated the effects of long-term stress on the neural dynamics of emotionally facial expression processing. Thirty-nine male college students undergoing preparation for a major examination and twenty-one matched controls performed a gender discrimination task for faces displaying angry, happy, and neutral expressions. The results of the Perceived Stress Scale showed that participants in the stress group perceived higher levels of long-term stress relative to the control group. ERP analyses revealed differential effects of long-term stress on two early stages of facial expression processing: 1) long-term stress generally augmented posterior P1 amplitudes to facial stimuli irrespective of expression valence, suggesting that stress can increase sensitization to visual inputs in general, and 2) long-term stress selectively augmented fronto-central P2 amplitudes for angry but not for neutral or positive facial expressions, suggesting that stress may lead to increased attentional prioritization to processing negative emotional stimuli. Together, our findings suggest that long-term stress has profound impacts on the early stages of facial expression processing, with an increase at the very early stage of general information inputs and a subsequent attentional bias toward processing emotionally negative stimuli.

1. Introduction

Studies in animals and humans have shown that long-term exposure to stress has a variety of consequences on cognition, emotion, and behavior (Lederbogen et al., 2011; Lupien et al., 2009; Schwabe et al., 2008). More specifically, participants suffering from long-term stress typically showed cognitive deficits (e.g., Kirschbaum et al., 1996; Liston et al., 2009; Wu et al., 2014) and augmented emotional responses (Lupien et al., 2009).

Behavioral research reported that a high level of long-term stress was associated with greater affective reactivity (van Eck et al., 1998). It was also reported that individuals who are exposed to long-term stress perceived more negative emotion, such as anxiety and depression (Jun and Choi, 2015; Spada et al., 2008), and exhibit more negative emotional behavior, such as anger/hostility and aggressive behavior (Haller and Kruk, 2006; Sprague et al., 2011). These findings are particularly relevant for patients with disorders associated with long-term stress, such as major depression and anxiety disorder (McEwen, 2004; McWilliams et al., 2003; Rimmele and Lobmaier, 2012). Recently, some studies explored the underlying neurocognitive mechanism of these behavioral alterations under long-term stress (Golkar et al., 2014; Lederbogen et al., 2011). Functional magnetic resonance imaging (fMRI) results showed that a period of exposure to a stressful social environment (i.e., city living) was associated with increased amygdala activity (Lederbogen et al., 2011). In addition, long-term stress exposure impaired the connectivity between amygdala and anterior cingulate cortex (ACC), which correlated with the ability to down-regulate negative emotion (Golkar et al., 2014). There is, however, little knowledge about the dynamic processes when these alterations occur.

Event-related brain potentials (ERPs), with their higher temporal resolution, can be used to distinguish the neural sub-processes involved in behavior and have been utilized to investigate dynamic information processing (Hillyard and Kutas, 1983). By using ERPs, researchers are able to reveal the distinct effects of stress on the different processing phases. For example, one study found that early stages of visual processing were enhanced and late stages were attenuated when participants were under acute stress, suggesting that acute stress exerts dissociable effects on different stages of information processing (Shackman et al., 2011).

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* Corresponding author at: Key Laboratory of Behavioral Science, Institute of Psychology, Chinese Academy of Sciences, 16, Lincui Road, Chaoyang District, Beijing, China.
E-mail address: wujh@psych.ac.cn (J. Wu).

http://dx.doi.org/10.1016/j.ijpsycho.2016.08.010
0167-8760/

Facial expressions are often used in ERP studies as they are one of the most important emotional signals for humans (Eimer and Holmes, 2007). Previous researches have proposed the models of face processing (e.g., Bruce and Young, 1986; Haxby et al., 2000) as well as the related ERP components (Calder et al., 2011 for a review). Several components, including occipital-temporal P1 and N170, fronto-central P2, and central-parietal P3 are involved in the different stages of face processing (Eimer et al., 2003; Luo et al., 2010). The effect of emotional facial expressions begins as early as the P1 component, which reflect coarse perceptual discrimination of faces (Eimer et al., 2003; Vuilleumier and Pourtois, 2007). N170 reflects the structural encoding of facial features and configurations (Itier and Taylor, 2004; see Eimer, 2011 for a review). Enhanced processing as indicated by N170 effects were found for emotional expressions (Blau, Maurer, Tottenham, & McCandliss, 2007; Rellecke et al., 2012), though there are still debates about the emotional modulation on N170 (e.g., Eimer and Holmes, 2002). P2 is an early fronto-centrally distributed positivity which peaks approximately 180 ms after stimulus onset (see Eimer and Holmes, 2007 for a review). It is sensitive to the affective content of visual stimuli, reflecting rapid detection of salient facial emotions and the mobilization of attentional resources (Bertsch et al., 2011; Eimer and Holmes, 2007); P3 reflects a higher-level cognitive process, for example, distinguishing the emotion of facial expression (Campanella et al., 2002; Luo et al., 2010). Previous results have shown the increased P3 following the emotional compared to neutral faces (see Hajcak et al., 2010 for a review).

Several ERP studies have reported that stress or alterations of stress hormones alter neural activities to facial expressions (Bertsch et al., 2011; van Marle et al., 2009; van Peer et al., 2009). For example, participants in the higher stressful provoked condition showed increased occipital P1 amplitudes compared to less provoked participants for all facial expressions (Bertsch et al., 2011). Also, larger right N170 amplitudes to angry faces were reported when participants were under the social evaluative stress of public speaking (Wieser et al., 2010). As to the stress hormones, the oral administration of cortisol decreased the amplitude of early fronto-central P2 for faces, particularly for negative expressions (e.g., angry faces) in both healthy participants (Bertsch et al., 2011) and in patients with social anxiety disorder (van Peer et al., 2009). These results indicated that stress may enhance the early stages of face processing by increasing the attentional prioritization to the salient stimuli, especially to the negative emotional stimuli. Similar results were found in individuals with disorders associated with long-term stress. For example, anxious individuals showed higher amplitudes of P1 to faces regardless of expression, indicating the hypervigilance to the social salient stimuli (Peschard et al., 2013). Besides, an early attentional bias for angry faces as indexed by P2 amplitudes were found in individuals with social anxiety disorder. But some researchers did not find effects on these early components (Weinberg and Hajcak, 2010). These findings were either induced by a short period of stress, or within a population with stress-related disorder, and cannot be generalized to the healthy population. Moreover, given that acute and long-term stress impact body and brain differently (McEwen, 2004), the neural basis of how long-term stress impacts on emotional expression processing still remains largely elusive.

Therefore, we recruited healthy participants to investigate the mechanism of emotional information processing under stress. The present study aims to investigate the effects of long-term stress on neural dynamics for processing emotionally salient stimuli (i.e., facial expressions). The participants in the long-term stress group were college students who were undergoing a period of psychological stress for around six months as they prepared for a major academic examination. Previous research in humans has utilized long-term preparation for academic examination as a naturalistic stressor (Gonzalez-Cabrera et al., 2014; Liston et al., 2009). In this study, participants in the stress group prepared for the National Postgraduate Entrance Exam (NPEE), which is one of the most important and highly competitive exams within the national educational system (Duan et al., 2013). Normally, students begin to effortfully prepare for about half a year before the exam. The acceptance rate into a graduate program following the exam has been <33% over the last ten years (Sohu.com, 2014). Questionnaires on the duration of preparation for the exam and perceived stress level were collected to assess the long-term stress.

Since previous studies have demonstrated that long-term exposure to stress was associated with greater reaction to emotional stimuli (Golkar et al., 2014; Lederbogen et al., 2011; Sprague et al., 2011),we predict that long-term stress would augment sensitivity to processing of emotional expressions. As some results showed that stress may enhance the early attentional distribution to the salient stimuli, which is indexed by greater amplitudes of P1, N170 and P2 to facial expressions (Bertsch et al., 2011; van Peer et al., 2009; Wieser et al., 2010), we are expected enhanced amplitudes of early components to facial expressions for stress group compared with non-stress controls. Specially, we predicted increased P1, N170 and P2 to negative expressions for stress group compared with the control group. Besides, we will also examine whether the late ERPs to the facial expressions are affected by long-term stress.

2. Method

2.1. Participants

Sixty-three healthy male undergraduate students with normal or corrected-to-normal vision took part in the study. Forty-two of them (stress group) had spent about six months of preparation for the NPEE. The other 21 students were from the same college, matched in terms of age and grade, but did not participate in any academic examinations or interviews within one month before or after the experiment. Only male students participated in this study to avoid any confounding sex influence on stress effects (Backovic et al., 2012; Baeken et al., 2012; Weekes et al., 2008). Inclusion criteria were no history of serious diseases, such as psychiatric or neurological disorders or any other major chronic physiological disorder; no chronic use of any neurological, psychiatric, or endocrine medicine; no current diseases; and no medication use within two days of participation in the study or irregular life style. Overnight shift workers or participants with irregular circadian rhythm, excessive alcohol users (more than two alcoholic drinks daily), or nicotine users (more than five cigarettes a day) were excluded. All participants were assessed with the Life Events Scale (LES; Nakamoto and Mori, 2008; Willemsen et al., 2010) to exclude other major life stressors of the past and within one month in the future.

Three participants were excluded from the data analysis because of excessive ocular and muscle artifacts (over 50% trials were removed due to artifacts). Finally, 39 participants in the stress group and 21 participants in the control group remained. The stress group and control group were matched with respect to age (M ± SD: stress group 22.1 ± 1.0 years vs. control group 22.1 ± 1.0 years). All participants provided informed consent and received monetary compensation for participation. The experiment was approved by the Ethics Committee of Human Experimentation at the Institute of Psychology, Chinese Academy of Sciences.

2.2. Stimuli

The stimuli consisted of photographs of six actors (three female), which were taken from Asian faces in of the NimStim set of facial expressions (Herman et al., 2008; one female and one male), the Japanese and Caucasian Facial Expressions of Emotion (JACFEE) (Biehl et al., 1997; one male), and the Chinese Facial Expressions of Emotion (Wang and Markham, 1999; two female and one male). Each actor displayed a happy, neutral, and angry expression (see Fig. 1). A total of 18 photographs were used in the experiment. All the faces were removed hair, clothing, background and the other external features. Stimuli were equated in terms of size, gray scale parameters, luminance,